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ABSTRACT

This paper argues that academic service learning at the undergraduate level provides an accessible and powerful crucible for exploring a career in teaching while also providing needed literacy experiences for children. Undergraduate service learning programs can include direct and authentic experiences that enroll, engage, and stimulate both undergraduates and the children they teach to learn and apply science. The academic service learning experiences described herein are available in childcare settings in most communities every day. Reflection and inquiry are key elements and serve as the bridge between science literacy and service learning. In these programs, the educational truism "learn by doing" is employed to serve both science literacy and learning to teach. The paper's aim is to describe and define an operating undergraduate program that works to simultaneously develop the science literacy, career awareness, and social capital of undergraduates and children. (Contains 23 references.) (Author/YDS)

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SCIENCE LITERACY IN THE CRUCIBLE OF SERVICE LEARNING

(RIGOR AND RELEVANCE — DEVELOPING CONNECTIONS BETWEEN SCIENCE, EDUCATION, COMMUNITY AND CAREER)

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Abstract:

In this paper we argue that academic service learning at the undergraduate level provides an accessible and powerful crucible for exploring a career in teaching while also providing needed literacy experiences for children. Undergraduate service learning programs can include direct and authentic experiences that enroll, engage, and stimulate both undergraduates and the children they teach to learn and apply science. The academic service learning experiences described herein are available in childcare settings in most communities every day. Reflection and inquiry are key elements and serve as the bridge, so to speak between science literacy and service learning. In these programs the educational truism "learn by doing" is employed to serve both science literacy and learning to teach. Our aim is to describe and define an operating undergraduate program that works to simultaneously develop the science literacy, career awareness and social capital of undergraduates and children.

Introduction:

We explore three interactive themes related to academic service learning and learning to teach: Educational experiences that provide an opportunity to learn science by teaching science; learning experiences that develop reflective practice and sense of educational ownership and design; and, how inquiry and reflection serve as an effective

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bridge between content and context. We begin by distinguishing what makes academic service learning distinct and unique, then describing the current shortage of qualified teachers in the schools, and the state of science education. We define and explain our interactive areas for academic service learning in science. We describe a course designed and taught at the University of California at Davis designed to support undergraduates in becoming comfortable with using inquiry-based science programs and materials to develop an understanding of science and using constructivist teaching methods with children. Sample inquiries and reflective interactions among the undergraduates along with their work in after-school childcare are presented. The case is made that academic service learning that has constructivist and reflective curriculum components and a significant amount of reflection on practice helps fructify the promise of service learning to improve science literacy and civic engagement. A summary that defines the lines of evidence use to assess the work of the undergraduates is presented. Also presented are the lines of evidence that make both undergraduate and child learning visible.

Background:

Academic Service Learning — All service learning is not equal. In his stirring description of service learning, (2000) James Kielsmeier boldly states that "at every level of schooling, youth participation in service is at an all-time high." And then goes on to assert "...the service-learning movement demands nothing less than reconceptualizing the role of young people in modern democratic societies, particularly in the context of schooling (p. 652). One can argue that this dominant view of citizenship development and community development vis-à-vis service learning is an important aspect of developing social capital within our society. However more can be gleaned from service learning by including a focus on bringing academic aspects into the forefront. What distinguishes the academic service learning course from a service learning course is the role and focus on inquiry and reflection in relation to academic content, thereby making learning authentic and visible.

American Education, the past two decades: During the past two decades public education in America has experienced an accelerating emphasis on "the standards

movement" and its handmaiden, testing. Lagemann (1989) speaking of traditions of educational research, claims "one cannot understand the history of education in the United States during the twentieth century unless one realizes that Edward L. Thorndike won and John Dewey lost" (p. 185). As we begin the 21st century we find the interest in repeated quantitative analysis continues. The effects of continual testing can, in some ways, be compared to a farmer expecting a pig to gain weight as the result of repeated weighing. Howard Gardner (2002) notes that "although there is consensus among cognitive psychologists "that children must construct knowledge for themselves; they cannot simply be 'given' understanding of any important issue. This insight – shared by thousands of cognitive researchers all over the world – does not prevent legislators from calling time and again for 'direct instruction' and 'drill-and-kill' regimens"(p. 49).

A troubling situation in our schools is that many areas of the country are experiencing teacher shortages and are hiring unqualified teachers on "emergency permits." For example, California currently has more than 40,000 teachers in public school classrooms that do not have teaching credentials. Specific to this study, the teaching of science in the elementary grades is generally uneven according to studies dating back to the 1960's. Although the National Science Foundation and other agencies have invested hundreds of millions of dollars in curriculum and teaching skills projects the unevenness continues according to the latest (2000) TIMMS data. The unevenness has been attributed in part to a generalized avoidance of science as an area of study by undergraduates going on to receive elementary teaching credentials.

The social landscape in America; the past two decades: The years 1980 – 2002 have seen broad shifts in the American economy, with swings from the heady heights to gut wrenching lows in the Dow Jones. In the workplace jobs are created and lost seemingly overnight, meaning that people have to seek new jobs, often in new fields. Retirement savings and investments have waxed and waned. Recent events have brought lawsuits questioning the ethics of America's captains of industry, while spawning hundreds of lawsuits. These same twenty years have seen the birth of the "Information Age" and the rise of the Internet and use of personal computers.

During the same time America has experienced a myriad of social changes including population diversity and an increased polarity between the 'haves' and the 'have-nots'. There have been significant changes in the definition of "community" as

described by Robert Putnam in Bowling Alone (2000). These rapid and hard-to-predict changes have exacerbated the need for education that not only provides teachers and children with knowledge and information, but also with skills and experiences that help them better understand and live in a changing social and economic landscape.

Science learning and the development social capital: During the past decade interest in and use of the concept of social capital has increased among educators (Dika & Singh, 2002). The concept of social capital in a theoretical framework was first described by Pierre Bourdieu (1986) in his distinction of the three sources of capital (economic, cultural, and social) and elaborated and expanded by James Coleman (1988). Although the theories of Bourdieu and Coleman differ, each define social capital as the benefits accruing to individuals or families by virtue of their ties with others (Dika & Singh, 2002). Service learning programs provide a rich and authentic opportunity for teachers and children to develop social capital through project-based activities. For example, in the YES academic service learning course we use the learning cycle instructional method (Karplus; 1977, Marek & Cavallo; 1997) that provides for independent inquiry in the "exploration" phase of the activity, and for interdependent inquiry in both the "concept development" and "concept application" phases. The "concept application" phase is critical to academic service learning programs. Through the opportunity for the learners to compare their observations, data and theories they learn to use different lines of evidence for they are learning directly from their interactions with worms, snails or other organisms and materials and working directly with their colleagues. Their observations and "meaning making" are critical for their co-construction (and often re-co-construction) of knowledge and understanding.

Science teaching, science, and using social interactions in teaching science: The academic standards tests used in California do not test science mastery until grade four. This fact, combined with the well documented studies detailing elementary school teachers' lack of preparation and confidence in teaching science, means that for most public school students science isn't taught until grade four. The irony in this is that even when science is taught, the overall goal is to impart information and knowledge to the student, so that he/she may be successful on the test. This educational scenario is contrary to how scientists go about inventing and constructing knowledge, and how scientific investigation proceeds.

Many historians of science have documented how science (as a discipline and body of work) proceeds and develops, but perhaps *The Structure of Scientific Revolution*, Kuhn's descriptive analysis of science, is the best known popular work (Kuhn, 1970). In science the answers are not in the back of the book, or as Richard Feynman stated "Science is the belief in the ignorance of the experts." Science relies on evidence, theories, prediction, hypothesis and continuous inquiry.

In our Youth Experiences in Science (YES) academic service learning program for undergraduates interested in becoming teachers, our underlying assumption is that knowledge is invented. People invent knowledge. It is a human enterprise to invent and construct knowledge, Therefore the best way of learning about science and science teaching is to actually conduct inquiries of your own.

Some examples of invented scientific knowledge include Pythagorus developing the Pythagorean Theorem, Joseph Priestly discovering oxygen, Madame Curie isolating penicillin, Jonus Salk and his colleagues developing a vaccine for polio, and Barbara McClintock winning the Nobel Prize for her work in corn genetics. The instructional model used in YES differs from didactic pedagogical structures as it more closely follows the flow of inquiry and invention found in scientific practice. YES uses constructivist pedagogical structures related to the creation and/or acquisition of knowledge. That is the children are engaged in inquiring into natural phenomena, and the undergraduate participants are engaged in inquiring into effective teaching practices.

An additional dimension of the pedagogy in YES is helping the undergraduate novice teachers explore dimensions of their own power and control in the classroom, arguably an issue for most beginning teachers. Yukl (1989) defines power as "An agent's potential influence over the attitudes and behavior of one or more target persons."

What sort of educational program would provide academic rigor, individual and community relevance, and the opportunity to build science and social literacy, skills and knowledge in an authentic and visible way? What sort of teaching experiences help naïve teachers unpack and learn the craft of teaching, review their role as power broker in the classroom, and learn to reconstruct their view of teaching<->learning. What are the critical elements and the catalyst to blend the academic and service features to make an effective academic service learning course for science literacy and effective teaching?

Human Development 192 – The Youth Experiences in Science: Implementation and outcomes of an exemplar course: The Youth Experiences in Science (YES) academic service learning course is offered to undergraduates at the University of California at Davis. The course is housed in the Department of Human and Community Development and is usually taken by undergraduates interested in becoming elementary teachers. The YES course is designed for undergraduates to learn to present science activities that develop science literacy through investigative skills and hands-on activities in after school settings. The course is organized in such a way that teams of 3-5 undergraduates form teaching teams that go to local after school childcare sites and use inquiry-based science programs with children enrolled at the sites. The course includes guided observation of the children, university classroom time where the undergraduates learn to use the materials through peer teaching, and discussions about what constitutes best education practices, and ways to assess learning. The inquiry-based science materials used are those developed as part of the Youth Experiences in Science Program, an award-winning NSF-funded materials development project specifically targeting children in after school childcare. The YES curriculum materials are hands-on inquiries of intrinsic interest to children 5 to 8 years of age. Pedagogically, YES units incorporate hands-on, inquiry-based science activities with cooperative learning. They focus on helping young children learn to use the scientific thinking processes of observing, communicating, comparing, and organizing. Each unit includes six sessions. The undergraduate teaching teams are given the leader's manual and the materials to conduct the YES program; they also are provided with training sessions in the use of the manual and materials. The leader's manual includes prompts to guide the undergraduate "teaching partners" in planning and implementing the activities. The prompts include lesson overviews, background information, a materials list, planning tips, suggested teaching actions, and some specific questions to get the activities started. The lessons incorporate the three-step learning cycle, whereby the undergraduates assist and encourage young learners with exploration, concept development and concept application to promote understanding.

In addition to the materials used at the childcare site each instructional unit includes supplemental materials and activities in "take home" loaner backpacks related to the curriculum to encourage family involvement in real-life home settings. Also, the

undergraduates put on "Family Science Activity Evenings" where the entire family is invited to come and engage in "sciencing." Several of the YES units also include learning centers for use in classrooms.

We, of course, did not invent this model. We only adopted it to an academic service learning model that encourages undergraduates to begin along the path of reflective practice described by Donald Schön, (1983), and the writings of John Dewey. This view of authentic education has been around for a long time and can be found quite prominently in the Reggio Emilia early childhood education system, the recent writing of Jerome Bruner and Howard Gardner. This model exists in many schools throughout the US that have adopted the engaged approach to teaching and learning.

Some discrete instructional structures are used in the HD-192 YES academic service learning course. The ones identified here are described with the learner as the point of reference. They are presented here in a sequence beginning with a structure in which the students are generally more dependent on the teacher not only for information but also on how well they are doing. Subsequent structures progress toward ones where the student is more interdependent, with the information and knowledge along with evaluation being generated by peer group and teacher interactions. This sequence also goes from least to most constructivist with increased density in terms of social interchange among and between students. The structures scaffold and each can include previous ones (except, of course, the first structure). In practice, undergraduates used one or more of the structures and arranged them according to the goal of their activity/lesson.

- The first structure is a dependent interaction (being taught), where the teacher is presenting the knowledge/information and the learner's responsibility is to learn/remember the knowledge for a later use (typically, a test). In this case, the learner is dependent on the teacher for being taught the knowledge/information, and for knowing how well he or she did. How knowledge is made visible in this structure is oftentimes through question answering, and testing. Examples of this model include teacher taught lessons, videos, assigned readings, and listening to presentations.

- The second structure is an individual's independent interaction with materials (discovery), wherein the learner is actively engaged in finding something out independently, and without being "taught." In this case the learner is independently creating, discovering, and/or constructing the knowledge and information. How

knowledge is made visible is through share-and-tell presentations, papers, reports and displays. Examples are science fair projects, and independent studies.

• A third type of structured learning interaction is where a small group of learners (typically a triad) are working together to solve the same general problem. In this scenario the learners are co-constructing the knowledge by designing and carrying out a project of some sort. This structure includes peer (and sometimes teacher) interpersonal interactions, data gathering, reflection and negotiation. How knowledge is made visible is through verbal and/or written presentations of the findings, results from the project and displays. The outcomes may be structured to have either an individual or group focus. Examples include group projects, lab partner interactions and project-based learning.

• The fourth type of learning structure (academic service learning) includes a larger group of participants working together and solving a larger problem typically issue-based that has social implications for the community. This structure includes interdependent interactions, data gathering, reflection data presentation and negotiation. It differs from the third type, in that re-co-constructions occur among group members due to the increased interactions necessitated by an extended period of time, a larger group and larger problem. It also differs in that it includes reflection and community-based social implications. Academic service learning involves public service and public presentations in addition to academic presentations of process and findings. Of course, each of these structures is a useful pedagogical tool, used for different purposes and outcomes. Third and fourth structure interactions build social capital as well as knowledge and skills.

<u>The role of reflection as the catalyst in the crucible of academic service learning.</u> What distinguishes the academic service learning course from a typical service learning course is the role and focus on academic inquiry and reflection. Academic and educational inquiries, designed by each of the course participants are the catalyst to focus their investigations conducted during their "service" into areas of personal and professional interest. The classmates assist each other in gathering data and reflecting on meaning. In the sample course presented here reflection is the key to growth and learning, the means of reliving or recapturing experience in order to make sense of it, to learn from it, and to develop new understandings and appreciation. Reflection comes

from the Latin word *reflectere*, which means to bend back. Wade and Yarborough use a mirror metaphor to describe the process of reflection..."Imagine a mirror; as a mirror reflects a physical image, so does the reflection as a thought process reveal to us aspects of our experience that might have remained hidden had we not taken the time to consider them," (1966 p. 64). The Latin root of "educate" is *educare* - to draw out. Educators such as John Dewey have made much of the reflective process as a way of drawing out (expanding) thinking process for both student and teacher. For example in *School and Society* he explains "the statement so frequently made that education means 'drawing out' is excellent, if we mean simply to contrast it with the process of pouring in...The child is already intensely active, and the question of education is the question of taking hold of his activities, of giving them direction. Through direction, through organized use, they tend toward valuable results, instead of scattering or being left to merely impulsive expression" (Dewey, 1900. pp. 53-54).

LaBoskey (1993) suggests to teachers that "individuals need to learn how to process their experiences; they need to bring other knowledge, theoretical principles, and alternative interpretations to bear in any analysis of that experience; in short, they need to be reflective (p. 10)." We argue that the combination of inquiry to gather and aggregate evidence and data, and the use of reflection on the results of inquiry begin the educator on the path of reflective practice.

<u>Lines of evidence – Making learning visible</u>.

• Evidence of undergraduates learning core processes of science and becoming more comfortable in teaching science were taken from pre-post questionaires and semantic differential instruments. Their view of who does science was assessed with a "draw a scientist" projective measure. The undergraduates each designed an inquiry that included two other undergraduates as research assistants for the study. For example if there are 25 students there are 25 inquiry projects going on. In addition, each participant is helping collect data for two other projects. The projects are designed independently, then reviewed by the instructors as to whether or not they meet the criterion for an undergraduate research study, and meets protection of human subjects criteria. This study is one of four major pieces that are assessed for the final grade. A second measure comes from the supervision observations by the university faculty and observations of supervising teacher/child care site director. This aspect focuses on

involvement and assessment of teaching craft skills and the ability to organize and implement an effective program. The third measure is the undergraduate's participation in class discussions, quality of reflective papers and self-assessment. The final line of evidence is the portfolio of the individual's progress and learning as a teacher and learner. The portfolio includes multiple lines of evidence assembled by the undergraduate. Typical lines are videotapes, letters from parents and students, reflective writing based on each day of teaching and class meetings, samples of children's work, classroom artifacts, photos of students (where allowed) and results of interviews with students and peers.

Also how the undergraduates inquire into assessment of the children is discussed. reflective social interactions that extend and elaborate knowledge and scientific literacy, teaching skills and build the social capital of the participants are presented and described.

• Evidence of children learning from the HD-192 YES experiences. The YES program taught by the undergraduates did not have the intent of guaranteeing learning in all six dimensions of child science presented in Table 1, for each child. However, the undergraduates were prepared to offer opportunities for development in children of a complex array of activities that define the complex model. For example, YES provides opportunities and direct instruction in observation, counting, and generalizing. However, it equally emphasizes the spontaneous transformations of "messing about," (Hawkins, 1970) play, and fantasy (Piaget, 1970) with the materials presented in each lesson. For another example, lessons on worms presented vocabulary and concepts and also encouraged children to talk about raising worms at home with playmates.

In analyzing the impact of the undergraduates on the YES child participants it was clear that the undergraduates were viewed as an esteemed class of individuals by the children…that is they were late teens and young adults who were lively, engaged, expressive, and exhibited an interest in working and playing with them. This in turn made the undergraduates more interested in working with the children.

The YES instructional sessions foster mutual child inquiry by dyadic communications ("look at this!") or by groups of children's sense of what is important including questions such as "how do we get the snails to come out of their shells?" and "can a snail pull a toy car?" The program emphasizes the opportunity for children to direct their own studies or to follow activities suggested by the undergraduate teachers. YES does not strive for children's answers that are correct to generalized standards, but rather for conclusions that are correct by being observable vis-à-vis their own investigations and immediate experience with the materials.

Thus, the *effectiveness* of the YES program is defined by evidence of visible behavior on the part of children engaged in the six dimensions of scientific behavior and the continuation of the behaviors over time and in other locations. Many of the demonstrations of learning in YES show developmentally early versions of what later develops into more mature learning. For example the observations made by children do not show the exhaustive and systematic identification of all variables expected of older science students but rather the young children's versions are truncated to briefer, more idiosyncratic *proto-processes* which satisfy the immediate needs of the child to complete investigations in the YES activity to her own satisfaction.

Demonstrations or evidence of effectiveness in YES should be apparent to the undergraduate instructors, the children themselves, adult assistants who staff the child care centers, parents involved with their children after the instructional sessions, and expert observers who watch the instructional sessions in person or on videotapes. Thus, the data of this study involve the reports of each of these groups.

Data for this study were obtained with a series of interviews, focus groups, videotape analysis, instructional session observations (non-intrusive and intrusive), and photograph analysis by children.

Content analysis of these data sources identified six components of child science in YES that are presented in Table 1. Each of the components is discussed in the following sections using phrases quoted from data sources.

Table 1: Components of Child Science Observed in YES

Perform scientific processes
Transform materials and events
Construct ideas, meaning, learning
Get information, develop concepts
Carry out group theme studies
Relate to other settings and people

• Perform Scientific Processes

Children Showed Early ("Proto") Forms of Scientific Processes. For example, in making observations, the children were seen to observe using different senses. Children were also using other procesesses and proto-processes and child observation data included "watch," count, measure, compare, manipulate, isolate variables, generalize, predict, "test," "communicate," "explore," "question," and carry out "free form inquiry." The activities enabled children to "ask questions, give own answers, be creative, and be willing to change." Children often were seen to "take from an activity, and then apply it to what they do next." These operations were done in the context of materials and events including bubbles, worms, foods and other things that the children reported as interesting and intriguing. The materials and events not only were demonstrated by the children, but they were provided for further interaction and use by the children.

Children were seen to "observe on their own," "talk about what was observed," "relate information," "communicate, and talk through possibilities, plan ahead, and anticipate," "experiment in the form of 'let's see what happens,'" "not always follow what's laid out to do," and create "justifications." Comparisons were made as children "tested out different ways to make bubble foam." All of these child behaviors or indicators of mental actions were recognized as the child's ability to use scientific thinking processes.

Interviews with undergraduate instructors and with the adult child care staff, along with videotape analysis, suggest early but important versions of these generally recognized scientific thinking processes. Participants described the activity as "learning while playing" and "not quite measuring and comparing." The use of senses was called "broad observation." The process activity of the children was described as "science

readiness" in its level of application. Children were seen to be developing 'basics" and "stepping stones." Participants were certain in their identification of both appropriateness and value of these scientific processes.

Spontaneously Transform Materials and Events. Transformations are physical and mental acts whereby the child changes the given materials and events for her own purposes: curiosity, interest, intention, need, disequilibrium, or even boredom (Peterson, 1976). When the transformations are regularized they are recognizable as scientific processes such as observation and comparison. When transformations are used systematically they are recognizable as scientific inquiry. The YES activities enabled not only a systematic transformation of events and materials as characteristic of scientific processes, it fostered a more spontaneous transformation characterized as "messing about," "playing with," and "fooling around with." One observation was that "they didn't want to talk, they just wanted to play with the bubbles;" another was that "the kids didn't want to sit down and discuss the project, they wanted to **do** the project." It was said that this involvement "may not be recognized as 'science,' but it is an early form necessary for learning how to do science."

However, spontaneous individual activity also could lead to less cooperative behavior. Undergraduates said that at times "it can be hard for kids to work in groups" and that the children "wanted to be independent." Several noted that "it was easier for the girls to be cooperative than the boys."

Construct Ideas, and meaning. Children were observed to construct idiosyncratic concepts during YES activities. Often, particularly at the beginning, the undergraduate instructors tried to organize the learning to make the results uniform. However, they began to recognize that the children were eager to take the materials in directions that were of interest to them as individuals, and to interpret directions in ways that followed their own interests. This observation was recognition that the same activity did not lead to identical ideas, meaning, and learning outcomes in different children. Instead, the children were described as learning different details, facts, and phenomena. They "invented their own conclusions." The result was a "general openness to learning" that was expressed in individual ways, rather than as specific information acquisition.

Get Information, develop concepts. Undergraduates identified information acquisition as an important part of YES involvement. When asked about benefits, they

mentioned "learning vocabulary" and "learning processes" as outcomes. One kind of information specially valued was when children were successful at "memorizing." Worm body parts were used as examples of information by several undergraduates and adults. Another indicator of program success was that "kids didn't know, now they know."

Relate Activities and Learning to Other Settings Other Persons, Becoming Socially Collaborative. Most of the social interaction was to show and tell about the child's own idiosyncratic activity, or to tell others of their interests. There were many instances of multiple monologues in which the purpose of conversation was to participate with one's own reports. A second kind of social interaction was to notice another child's interesting actions and to begin to duplicate it as a start for developing their own individual interests (co-construction and/or duplication). Likewise, parents and children related their own continued science activities at home, play, and school; for example, many reports of continued bubble play were told to interviewers. Overall, the YES academic service learning course provides children the opportunity to engage in high quality, experiential, science activities in after school child care settings. Important benefits of development and learning are provided for both the undergraduate instructors, and the child participants. The effectiveness of the YES program provides a complete package for involving cross-age teaching, hands-on learning, and parent involvement. Project outcomes include: (1) the spontaneous, non-systematic, transformations of materials and events by the child participants, (2) the construction and application of ideas, meaning, and learning, (3) children are engaged carrying out group or otherwise socially transmitted studies, and (4) children relating the activity and other things they learned to other settings such as home and playground, or with other people including classmates, playmates and parents.

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